7. TROPICAL CYCLONE SUPPORT SUMMARY

7.1 AN UPDATED VALUE ANALYSIS OF JTWC WARNING SUPPORT

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A comprehensive analysis of the costs of western North Pacific DOD typhoon preparations, the value of JTWC support, and the cost effectiveness of the USPACOM Tropical Cyclone Warning System was accomplished. The study analyzes the warning process at JTWC, describes various typhoon strike scenarios, explains the value of credibility, considers both tangible and intangible costs and benefits, ascertains port/facility costs for typhoon preparation, illustrates the value of resources at risk, and finally computes the cost-benefit ratio of the Warning System. The analysis provides a baseline for future assessments whenever support requirements change. (It will be published as a NOCC/JTWC Technical Note.)

7.2 A TROPICAL CYCLONE WIND SPEED VERSUS DAMAGE SCALE FOR THE TROPICAL WESTERN PACIFIC

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and
Dr. Mark A. Lander
University of Guam

A scale that relates tropical cyclone wind speed to potential structural, agricultural, and coastal damage has been developed for use in the tropical western Pacific Ocean. The scale employs the basic model of the Saffir-Simpson Hurricane Scale which has been used for many years along the Atlantic and Gulf of Mexico coastal areas of the United States. It incorporates construction materials and plant life that are common to the tropical Pacific region, and considers the structural weakening of wood from termites and wet and dry wood rot. The scale also modifies expected storm surge values of the Saffir-Simpson Hurricane Scale to account for the effects of island near-shore bottom topography (such as fringing coral reefs) on storm surge, wind-driven waves, and near-coastal surf action. Because many of the islands of the tropical Pacific contain crops and shelters that are highly susceptible to damage by sub-hurricane-force winds, the scale addresses the potential damage from the winds and seas associated with tropical depressions and tropical storms as well as with typhoons. The scale has good potential for application in other tropical cyclone-prone areas in the global tropical belt. The paper will be submitted to a meteorological journal, and a User's Manual has been completed and will be published as an NOCC/JTWC Technical Note.

7.3 MIDGET TROPICAL CYCLONES: A SURVEY AND DESCRIPTION

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and
Lt Col Chip Guard
Joint Typhoon Warning Center, Guam

This paper attempts to distill from historical accounts, technical studies, and recent observations, a descriptive climatology of midget tropical cyclones (MTCs). A definition of the MTC is presented. Several examples of MTCs are provided to illustrate the special diagnostic and forecast problems associated with these storms. An argument is presented that the MTC is a unique subset of tropical cyclones possessing a unique set of characteristics, and not merely a continuum of smaller than normal tropical cyclones based solely on size. These unique characteristics are identified and a physical model is presented. Foremost among these are the presence of inner core winds only (no significant outer core winds), rapid intensity changes, and preferred areas for genesis under specific synoptic conditions. Techniques for analysis, satellite interpretation, and forecasting are presented. The paper will be submitted to a meteorological journal for publication.

7.4 AN EXPLORATORY ANALYSIS OF THE RELATIONSHIP BETWEEN TROPICAL STORM FORMATION IN THE WESTERN NORTH PACIFIC AND EL NINO-SOUTHERN OSCILLATION (ENSO)

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University of Guam

Observed annual tropical cyclone (TC) totals in the western North Pacific are virtually uncorrelated with any ENSO index, a finding which supports earlier work by Ramage and Hori (1981). The only statistically significant relationship found in this study between an ENSO index and a statistic of TC totals was the reduction in the number of Early Season storms during years when the Southern Oscillation index starts out relatively low and rises sharply by the middle of the year.

It is very clear that the ENSO cycle plays a major role in the interannual fluctuation of the annual mean genesis location of TCs in the western North Pacific. In order to show this relationship, the NOAA Climate Analysis Center's monthly values of the Southern Oscillation index were averaged in 11-month (March through January) intervals (<SOI>). When the <SOI> is low and the SST in the central and eastern equatorial Pacific is warmer than normal, the genesis region for TCs in the western North Pacific shifts eastward; when the <SOI> is very high and the SST of the central and eastern equatorial Pacific is cooler than normal (so-called, "la nina" or cold event conditions) the annual average genesis location shifts westward.

During a given year, the TC distribution and the preferred areas for genesis are governed primarily by the location and the behavior of the monsoon trough. ENSO plays a significant part in the complex behavior of the regional circulation of the western North Pacific, particularly with respect to the eastward extent of penetration of monsoonal westerly winds in the western North Pacific. During low <SOI> years, the monsoonal westerly winds penetrate further to the east than during most other years, and the average annual genesis location of the TCs is found east of normal. This eastward displacement of cyclogenesis is greatest during the Late Season of low <SOI> years (Figure 1). During high <SOI> years, the monsoon trough, on average, does not penetrate as far to the east as it does during low <SOI> years, and the annual mean genesis location is found west of normal, particularly during the Early and Late Season. Many of the TCs that form to the east of normal during the Mid Season of high <SOI> years are induced north of 20°N in low-level easterly flow by overlying or peripheral TUTT cells. Most of the TCs that form to the east of normal during low <SOI> years form south of 20°N at the eastern terminus of an eastward-displaced monsoon trough (Figure 1).

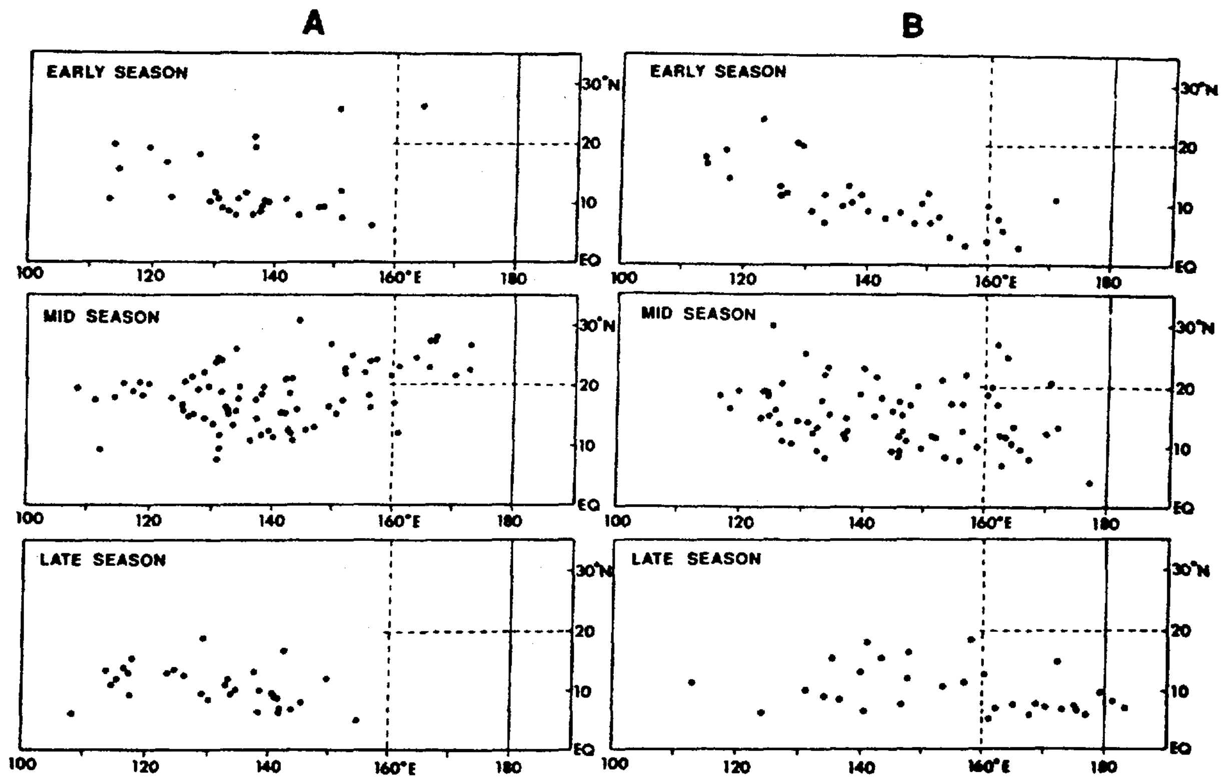

Figure 1. Origins of tropical cyclones by season (Early Season — March through mid-July; Mid-Season — mid-July through mid-October; Late Season — mid-October through January) for the five years during the period 1970-1991 with the five highest values of <SOI> (column A), and for the five years with the lowest values of <SOI> (column B). Note: origin is defined as the location where tropical depression intensity first appears on the JTWC final best track .

7.5 AUTOMATED TROPICAL CYCLONE BINARY INTERACTION ANALYSIS AND FORECASTING

Captain Steven C. Hallin, USAF
Joint Typhoon Warning Center, Guam

7.5.1 ANALYSIS

In order to update existing hand plotted techniques, an automated technique for the analysis of binary systems has been developed. This technique uses analytical techniques developed in previous studies (Brand, 1970; Dong and Neumann, 1983; Lander and Holland, 1993) which have emphasized the importance of plotting the tracks of the two tropical cyclones relative to the centroid, calculating the separation distance between them, and calculating orbit rates around the centroid. Typical features of a binary interaction, as seen in the centroid-relative tracks, are summarized in Figure 2.

The primary, and most reliable, parameter used in diagnosing the onset of binary interaction is the separation distance. The average distance at which binary interaction is initiated is approximately 750 nm (1400 km or approximately 12° of longitude) (Brand, 1970), although in practice, capture or escape can occur at substantially different distances. A real-time calculation of the orbit rates around the centroid provides another objective measure of the onset of interaction. To use the orbit rate in determining the onset of binary interaction,

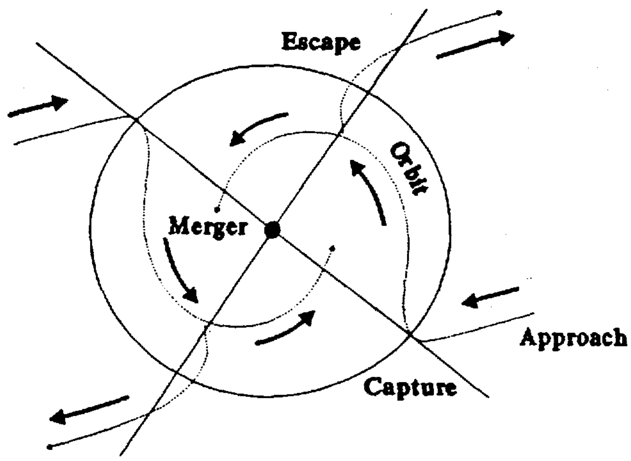

Figure 2. Model of binary interaction of two cyclonic, mesoscale vortices, containing the major elements of approach and capture, followed by mutual orbit, then release and escape, or merger (from Lander and Holland, 1993).

the following rule of thumb is applied: if the separation distance is greater than 750 nm, a delay of the diagnosis of binary interaction is suggested until a cyclonic orbit rate of at least two degrees per six hours has been established for 12 hours. If the separation distance is less than average, then six hours of any amount of cyclonic orbit rate should suffice to establish that interaction has commenced. Deviations from the idealized case shown in Figure 2 can be manifested as periods of transient binary interaction, periods of weak binary interaction, fluctuating orbit rates, and nonstandard capture and escape distances. These deviations may occur due to external influences or size variability in the tropical cyclones.

Figures 3 and 4 show the interaction between Typhoons Brian (25W) and Colleen (26W) in October 1992. Figure 3 is a common centroid-relative pattern for a binary interaction (Lander and Holland, 1993). In earth-relative coordinates, the system to the west will typically exhibit a slow, erratic, looping motion as occurred with Colleen. The other tropical cyclone, in this case Brian, will acclerate toward the northwest after a noticeable bifurcation in its track, and then track around the subtropical ridge as it escapes and recurves. In Figure 4, the significant cyclonic rotation started on 201200Z October at a greater than average distance, e.g. 12-18 hours before the separation distance reached the 750 nm threshold, and increased as the systems approached. Brian escaped the interaction on 231800Z October as indicated by the increase in separation. The actual tracks of Typhoons Brian (25W) and Colleen (26W) are shown in Chapter 3, Section 3.2 Western North Pacific Tropical Cyclones.

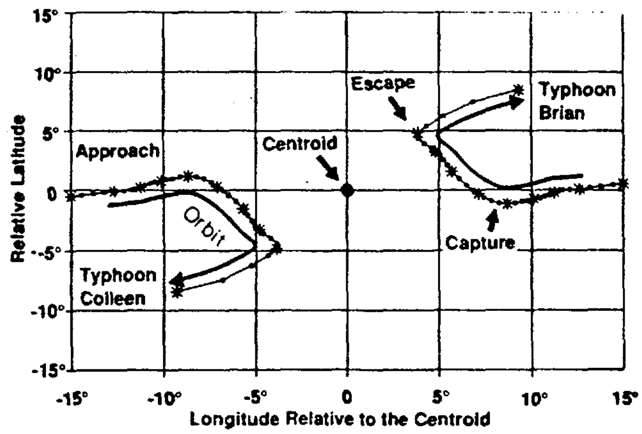

Figure 3 Centroid relative positions for Typhoons Brian (25W) and Colleen (26W).

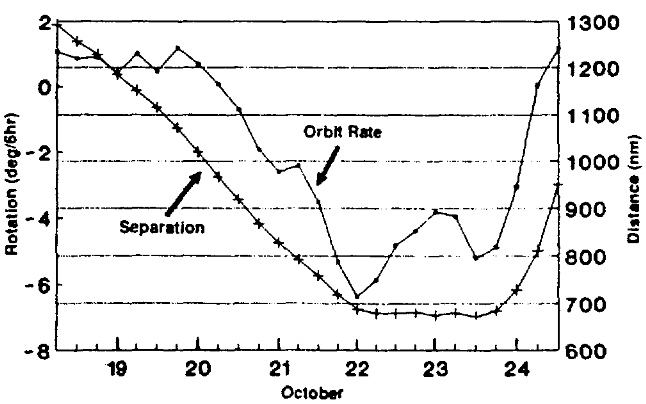

Figure 4. Time series of separation and orbit rate for the interaction between Typhoons Brian (25W) and Colleen (26W). Negative orbit rates indicate cyclone rotation.

The analysis of this particular binary interaction was of considerable operational importance since Brian's track deviation due to the capture in a binary orbit with Colleen directed the typhoon over Guam on 21 October. On 24 October, the interaction ended as Brian escaped into the westerlies.

7.5.2 FORECASTING

After determining that binary interaction is occurring, it is possible to calculate the forecast positions of the binary pair based on the separation distance and the orbit rate coupled with a forecast of the motion of the centroid. For this study, the centroid track forecast is based on CLIPER (Xu and Neumann,1985). The binary interaction forecast aid developed at JTWC, called FUJI, can then be applied. Its application should be tempered with an understanding that in the western North Pacific very few (less than 25%) of the binary systems merge and, the member of the binary pair to the northeast will most probably be the one to escape the interaction and recurve (Lander and Holland, 1993). Preliminary verification statistics on FUJI show reasonable one to two day guidance, which deteriorates at the three day point. The technique has been expanded to produce centroid track forecasts using other forecast models (e.g. NOGAPS) in addition to CLIPER.

7.6 TROPICAL CYCLONE INTENSITY AND THE LENGTH OF DEEP CONVECTIVE RAINBANDS AS DETECTED BY THE SSM/I SENSOR

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A set of 26 DMSP satellite passes over 15 western North Pacific tropical cyclones that occurred between 1990 and 1992 was studied to test the hypothesis that the length of rainband signatures on the SSM/I imagery can be related to the intensity of tropical cyclones. After reviewing the work of Glass and Felde (1990), which found a good relationship between the amount of deep convection (as measured on the 85-horizontally-polarized (85h) GHz channel) and intensity, the next step was to see if the length of the deep convective rainbands could be objectively measured on the 85h GHz channel. Each 85h GHz image was processed at a specific threshold temperature that best recovered the rainband detail, the arcs of the deep convective rainbands were curve-fitted to an overlaid 10° logarithmic spiral, and the arc length was measured in tenths of a complete wrap similar to the curved cloud band technique used by Dvorak (1984). The arc lengths were then plotted against the corresponding best track

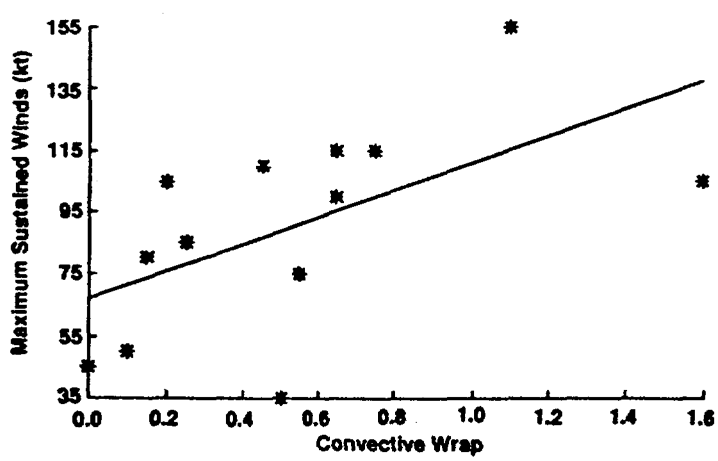

Figure 5. The relationship between the convective wrap of deep convection using a threshold brightness temperature of 205°K and maximum sustained winds for intensifying tropical cyclones. Parameters correlate at 0.82 which explains 90% of the variance. The standard error is 14 kt.

intensities. Separating the intensifying cases from the weakening cases, provided the most useful relationship. For the weakening cases, the use of a colder threshold temperature on the SSM/I data yielded better correlations between arc length and best track intensity. The results of the study are provided in Figures 5 and 6.

In summary, the hypothesis that the length of rainbands on the 85h GHz microwave channel can be related to the intensity of tropical cyclones appears to be valid. Because of the success of the Dvorak technique, which decomposes the visual and infrared satellite images into banding and central cloud features, the application of a Dvorak-like approach to the intensity estimation information latent in the SSM/I rainband signatures is appropriate.

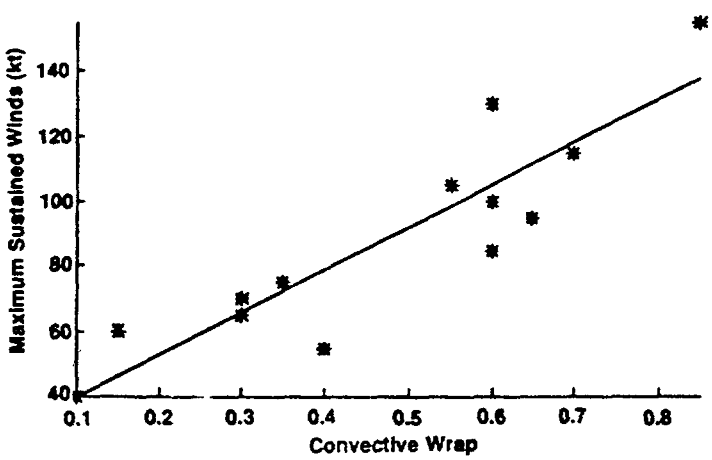

Figure 6. Same as Figure 5 except for weakening tropical cyclones using a threshold brightness temperature of 217°K. Parameters correlate at 0.34 and account for only 58% of the variance. The standard error is 28 kt.

7.7 TROPICAL CYCLONE FORECASTER'S REFERENCE GUIDE

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Development of a Tropical Cyclone Forecaster's Reference Guide continues. The guide consists of seven chapters. They are (1) Tropical Cyclone Warning Support, (2) Tropical Climatology, (3) Tropical Cyclone Formation, (4) Motion, (5) Forecast Aids, (6) Intensity, and (7) Structure. The first three chapters have been published as Technical Notes (available from NRL). The other four chapters are in preparation. The chapter-by-chapter publishing format not only makes the edition and inclusion of updated information easy, but also provides tropical meteorology training notes for aerographers. After all of the chapters are complete, they will be transferred to an interactive video disk format, saving considerable storage space which is especially important for shipboard use.

7.8 A REGRESSION MODEL FOR THE WESTERN NORTH PACIFIC TROPICAL CYCLONE INTENSITY FORECAST

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A regression model forecasting the tropical cyclone intensity in the western North Pacific was derived by using the nineteen-year (1971-1989) post-analysis best track data from JTWC which includes the date, time and location of the cyclone's circulation center, and the observed maximum sustained wind speed (1-minute average at 10-meter elevation). The term intensity refers to the estimated maximum sustained 1-minute surface wind speed associated with a cyclone. This model provides intensity forecasts for 12-hour intervals up to 72 hours. The verification of the model's forecasts for data from 1990 is discussed. An operational version of this regression model, Statistic Typhoon Intensity Forecast (SHIFOR), was delivered to the Fleet Numerical Oceanography Center for operational testing. This model is based on the SHIFOR model (Jarvinen and Newmann, 1979) used at the National Hurricane Center. A technical report on this model will be published.

7.9 AUTOMATED TROPICAL CYCLONE FORECASTING SYSTEM (ATCF) UPGRADE

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The ATCF has been operational at JTWC since 1988. The current system runs on an IBM-DOS operating system. NRL, Monterey is adapting ATCR to the UNIX operating system under the program direction of the Space Warfare and Systems Command. The new ATCF will use industry standard X-Window/Motif for window management and will communicate with the Tactical Environmental Support System (TESS 3.0). The first phase of the project is expected to be completed in the summer of 1995.

7.10 PROTOTYPE AUTOMATED TROPICAL CYCLONE HANDBOOK (PATCH)

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Marine Meteorology Division, Monterey, CA

PATCH is an expert system designed to provide tropical cyclone forecast and training guidance to JTWC for the western North Pacific Ocean. The scope of the project has expanded to include expertise pertaining to tropical cyclone formation, motion, intensification and dissipation, and structure and structure change. The motion section is under evaluation and in the future will include forecasting expertise currently under development at the Naval Postgraduate School. The expert system is an integral part of the ATCF upgrade.

7.11 TROPICAL CYCLONE MOTION-92 (TCM-92) MINI-FIELD EXPERIMENT

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The Naval Postgraduate School (NPS) and the Office of Naval Research (ONR) Marine Meteorology Program co-sponsored a mini-field experiment near Guam during July-August 1992. The Experiment Operations Center was located at JTWC, which provided space, shared its meteorological data bases and facilitated the TCM-92 operations. JTWC TDOs participated in routine meteorological discussions.

The objectives and organization of the experiment were described in the TCM-92 Operations Plan (Elsberry et al., 1992), which also summarized recent research that has investigated short-duration tropical cyclone track deviations. TCM-92 tested the following hypotheses:

1) Long-lived tropical Mesoscale Convective Systems (MCS) have a three-dimensional wind and thermal structure similar to a midtropospheric vortex in the stratiform rain region of a midlatitude MCS, and have sufficient horizontal extent to cause a mutual interaction with a tropical storm or weak typhoon via a Fujiwhara-type effect that results in track deviations of the order of 100 km a day.

2) Long-lived tropical MCSs that maintain a quasi-stationary position relative to an associated tropical cyclone cause approximately 100 km deflections in the cyclone track via a divergent circulation and its interaction with the symmetric vorticity field to create a wavenumber one asymmetric circulation.

3) Relative cyclone track displacement of a MCS and a tropical cyclone can be related to their radial positions within the horizontal wind shear field of an active monsoon trough.

4) Tropical cyclone genesis is caused by the merger of two or more interacting MCSs to create a single system with greater vorticity.

During the period of 21 July 1992 to 21 August 1992, USAF Reserve WC-130 aircraft and crews of the 815th Tactical Airlift Squadron, Keesler Air Force Base, Mississippi deployed to the western North Pacific. Operating from Guam, crews flew nine missions of 9-13 hours duration into tropical cyclones and nearby MCS to collect flight-level and dropwindsonde observations in support of the TCM-92 mini-field experiment as described in the NPS Technical Report (Dunnavan et al., 1992). A M.S. thesis at NPS by Captain Eric McKinley (USAF) compares the observations from the most pronounced MCS during Intensive Observing Period (IOP) 7 verses a weak MCS during IOP 1. Four papers describing the preliminary results from TCM-92 will appear in the Preprints of the American Meteorological Society 20th Conference on Hurricanes and Tropical Meteorology (Boothe et al., 1993; Dunnavan et al., 1993; McKinley and Elsberry, 1993; and Ritchie, 1993).

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